LOW PROFILE ANTENNA

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This Application is a Continuation of International Application No. PCT/US02/16919, filed May 30, 2002 (Published December 5, 2002, International Publication No. WO 02/097918 A1), which claims priority to U.S. Application No. 09/870,232, filed May 30, 2001 (Issued February 11, 2003, U.S. Patent No. 6,518,933 B2), all of which are hereby incorporated by reference in their entireties.

FIELD OF THE INVENTION

[0002] The present invention relates generally to antennas. More particularly, the present invention relates to antennas having a low profile for use in roadways, sewer manholes, and other applications where a low profile is desirable.

BACKGROUND OF THE INVENTION

[0003] The collection of data from sanitary or storm sewer networks and other underground or enclosed systems has become increasingly common and useful. For example, in an underground sewer network, flow monitors may be used to collect data such as depth, volume, velocity, and/or other measurable parameters in a certain location. When such monitors are used, it is often desirable to collect the data in a central location, such as a remote computer or data collection system, so that data from multiple monitors can be analyzed, stored, processed, compared, and/or presented to a user. Because of the impracticality of connecting monitors that may be located throughout such a sewer or other network to a central processor via direct wiring, it is desirable that such monitors transmit their data to a remote computer through a wireless communications medium.

[0004] The application of wireless technology to transmit and/or receive data from and/or deliver data to flow monitors requires a suitable antenna for reception and/or transmission. For example, sewer flow monitors are typically installed within a sewer network inside or near manholes in order to provide access for installation, maintenance, and repair. Thus, the monitor may communicate with a remote unit via a wireless transmitter that is also located near or within the manhole. However, if transmitter's antenna is mounted so that the antenna is below the manhole's cover, substantial losses in signal strength, such as RF energy losses, will result from factors such as signal attenuation and the fact that the antenna is mounted below the ground plane.

[0005] One solution to this problem is to mount the antenna above the ground, outside of the manhole. However, conventional antennas normally require a mast or pole type of mounting. Thus, conventional antennas have an elevation that renders them undesirable for use in many locations, such as roadways and sidewalks where vehicular and/or pedestrian traffic will flow. Thus, a shorter, or low profile, antenna is desirable in such a location.

[0006] Existing low profile antennas still require a substantial elevation above the ground surface. Examples of such antennas may be found in U.S. Patent No. 5,877,703, to Bloss et al. Such antennas are subject to abuse from, and may be damaged by, roadway traffic, such as cars, trucks, buses, and other vehicles, as the traffic drives over them, directly placing substantial loads on the antenna. Other roadway vehicles such as snowplows can cause even more damage to an antenna that is raised above the roadway. In addition, such antennas require modification to the manhole cover, such as the drilling of a hole, to connect the above-ground antenna to the underground flow meter. Such holes

are generally large, as they are also used as a means to secure the antenna to the manhole and/or to connect the antenna to equipment below the manhole cover.

[0007] Accordingly, it is desirable to provide an improved low profile antenna as disclosed herein.

SUMMARY OF THE INVENTION

[0008] It is therefore an object of the present invention to provide an improved low profile antenna.

[0009] It is an additional object of the present invention to provide an antenna having a profile that reduces or eliminates the susceptibility for damage of the antenna resulting from roadway traffic and from road-scraping implements such as snow plows.

[0010] It is another additional object of the present invention to provide an antenna having a profile that reduces or eliminates the risk of injury to pedestrians who might come into contact with the antenna (i.e. by tripping over it).

[0011] An even further object of the invention is to provide an antenna that is inconspicuous so as to be resistant to vandalism.

[0012] In accordance with a preferred embodiment of the present invention, a low profile antenna for receiving and/or transmitting radio frequencies includes a first elongated element made from an electrically conductive material, a second elongated element made from the electrically conductive material, and a cable that is conductively attached to the first and second elongated elements. The first and second elongated elements each have a height that is of a low profile and lengths that are substantially equal. The elongated elements are covered at least partially with a substantially non-conductive covering.

[0013] Optionally and preferably, the first elongated element and the second elongated element are positioned to extend in opposite directions, form substantially a straight line, and are separated by a gap to provide a dipole antenna. Also optionally, the first elongated element and the second elongated element are sized and positioned to fit within one or more grooves or recesses of a standard manhole cover.

[0014] In accordance with the above-described embodiment, the electrically conductive material preferably includes copper. The height that is of a low profile is preferably about one-fourth of an inch or less, or even more preferably flush with the mounting surface, and the optional substantially straight line formed by the first and second elements has a length that corresponds to an operating frequency band of the antenna. The length preferably provides an electrically tuned antenna that is capable of transmission in close proximity to a surface.

[0015] As additional options, the cable has a diameter that is at least as small as the diameter of a standard manhole cover opening, and the substantially non-conductive covering is comprised of at least one of rubber, plastic, non-metallic tubing, an adhesive, and a non-metallic substrate. The cable may also be connected to a transmitter and/or a receiver. Optionally, the antenna includes an adhesive material that is affixed to at least a portion of the substantially non-conductive covering. Also optionally, the elongated elements may be positioned within at least one groove or recess of a standard manhole cover, or they may be embedded within or flush with a traffic surface. In an embedded or flush application, the antenna may be fixed to and sealed within the mounting surface by epoxy formulations specialized for sealing the type of surface the antenna is being positioned on or within.

[0016] In accordance with an alternate embodiment, a method of installing an antenna in a low profile position includes the steps of locating a low profile dipole antenna in a position that is substantially flush with or embedded within a traffic surface, placing a cable having a first end and a second end so that the first end is conductively attached to the antenna, the second end is attached to at least one of a transmitter and a receiver located in a system under the traffic surface, and a portion of the cable located between the ends enters the system through an opening, coating the antenna with a substantially non-conductive covering, and substantially sealing the opening with a sealant.

[0017] Optionally, in this method, the position that is substantially flush with the traffic surface is about one-fourth of an inch or less. The non-conductive covering is optionally and preferably is comprised of at least one of rubber, plastic, non-metallic tubing, an adhesive, and a non-metallic substrate. Optionally and preferably, the dipole antenna includes two elongated elements having substantially equal lengths positioned to extend on opposite directions from a point, and the first end of the cable is attached to the elements at the point. Also optionally and preferably, the traffic surface is at least one of a manhole cover, a road, and a sidewalk, and the opening is a standard manhole cover opening, a storm sewer grate, or another opening that is substantially at or near ground level.

[0018] Also optionally to this method, the elongated elements of the antenna may be positioned within a groove cut into the mounting surface and sealed in place with epoxy.

[0019] There have thus been outlined the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described below and which will form at least part of the subject matter of the claims appended hereto.

[0020] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein, as well as the abstract included below, are for the purpose of description and should not be regarded as limiting in any way.

[0021] As such, those skilled in the art will appreciate that the concept and objectives, upon which this disclosure is based, may be readily used as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. 1 provides a perspective view illustrating several elements of a preferred embodiment of the present inventive antenna.

[0023] FIG. 2 provides a perspective view illustrating several elements of an alternate embodiment of the present inventive antenna.

[0024] FIG. 3 provides an end view illustrating several elements of the preferred embodiment of FIG. 1

[0025] FIG. 4 provides an overhead view of a preferred embodiment of the present invention.

[0026] FIG. 5 provides a cross-sectional view of a preferred embodiment of the present invention and FIG. 5A shows detail of a portion of that embodiment.

[0027] FIG. 6 provides a cross-sectional view of an alternate embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0028] The present invention provides an improved antenna having a low profile. The low profile allows the antenna to be used in locations such as manhole covers that are located in roadways or sidewalks, near irrigation systems, and in other locations where traffic may be present, as the low profile helps to protect the antenna as it is contacted by vehicular and/or pedestrian traffic. Preferably, the low profile allows the antenna to rest at or below the primary surface of the roadway or sidewalk in an indentation such as an expansion groove, a groove cut into the surface for mounting the antenna, a manhole cover groove or recess, storm sewer grate, or other similar location.

[0029] In a preferred embodiment, the antenna includes several elements. The elements of this embodiment include two antenna legs that are partially or completely made of a conductive material, such as copper or another metal. One antenna leg serves the function of a ground, the other is generally referred to as the positive side of the antenna. The legs are positioned in parallel with each other and form substantially a straight line, radiating in opposing directions from a central point. The conductive material may be molded or flattened to have a low profile, such as with a copper wire or copper tape. The flexibility allows mounting of the antenna onto a mounting surface. It is not necessary that the mounting surface be smooth, and in fact the mounting surface may be either smooth or irregular. For example, the mounting surface could be a groove, recess, or slot of a manhole cover or traffic surface, a storm sewer grate, or any other location.

[0030] The antenna legs are separated by a gap and are connected to a transmitter and/or receiver by a wire such as a standard RF coaxial cable. Preferably, the wire is connected to the antenna legs at or near the gap, i.e., a central point from which each antenna leg radiates in opposing directions generally forming a straight line. In this embodiment, the antenna generally follows the electrical and physical principles that are applicable to a half wave dipole antenna. The coaxial cable is of a diameter small enough to fit through a typical hole or slot in a standard manhole cover. Preferably, the wire is of a diameter not exceeding about one-quarter of an inch. Thus, modification of the manhole cover is preferably not required. Alternately, the present inventive antenna may be used with mounting surfaces such as manhole covers having no holes or slots, in which case modification of the manhole cover or other mounting surface to add a hole or slot to accept the wire will be required. In either case, when a small hole is used, the strength and integrity of the manhole cover or other mounting surface is better preserved. Nonetheless, it should be noted that larger diameter wires, and thus larger holes, may be used in accordance with the present invention.

[0031] The antenna wire may be led away from the antenna legs in any direction which suits the necessary mounting arrangement. For example, in the case of mounting the antenna on a flat or slightly contoured surface where only the antenna legs are to be exposed, the antenna wire may be positioned perpendicular to the antenna legs so that it may pass through the surface to which the antenna is mounted, such as through a hole or slot in a manhole cover. Optionally and alternately, the antenna cable may be routed along side the antenna legs until it reaches a suitable position to transition through or off the mounting surface.

[0032] Optionally and preferably, the antenna legs are partially, substantially, or entirely housed in a protective covering. The protective material helps to improve durability and protect the conductive elements before and after mounting. The protective covering is substantially, and preferably completely, non-conductive so that the protective covering does not interfere with the operation of the antenna. Preferably, the protective covering is also flexible. Although the protective covering may have either a greater or lesser degree of flexibility than that of the conductive elements, preferably the flexibility of the protective covering will be less than that of the conductive elements. For example, the protective covering may be made of rubber, plastic or other non-conductive material. This protective material may be in the form of a sleeve, encapsulate, sheet, or any other form. In addition, the protective covering may be attached to, or even replaced by a substrate such as a non-metallic semiconductor or circuit board substrate. The protective covering helps to reduce the risk of damage to the conductive elements during handling, transport, and installation of the antenna.

[0033] The conductive elements and the protective covering may be further encased in an external coating. This external coating may be included with the antenna, or it may be added when the antenna is installed in its final service location. The external coating substantially or completely seals the assembly against the intrusion of water or other fluids. It also serves to seal and protect the antenna cable to prevent water from entering the cable. The external coating is preferably an epoxy.

[0034] The final external coating, also referred to herein as an encapsulation material, is preferably a moldable material that exhibits high strength once cured, and it preferably has a tensile strength and is able to endure loads as high as several thousand PSI or higher. Preferably, it is moldable to the contour available on the mounting surface. The

encapsulation material preferably also has the properties of being impermeable to water, solvents, salts and other common such materials. Preferably, the external coating or encapsulation material is durable, machinable, and has fast curing properties to allow relatively quick installation, and use shortly after installation. For example, in a preferred embodiment, the external coating may be comprised of an epoxy, or of rubber or plastic with an adhesive, that serves to fixedly attach the antenna to a mounting surface.

[0035] The antenna wire, in the area where it is connected to the antenna legs, is also preferably covered or encapsulated by the protective covering and/or the external coating. In addition, the hole or slot through which the antenna wire passes through is also preferably filled with the protective covering and/or the external coating, thus substantially or completely sealing the antenna wire and the connections to the antenna legs against water intrusion. The encapsulation in this area also acts to secure the antenna wire and make it resistant to external loads that may be applied to the antenna wire in its normal usage.

[0036] It should be noted that, while the above-described embodiment is a preferred embodiment, additional variations are possible. For example, a single antenna leg may be used, or more than two legs may be used, and the leg or legs may be positioned in a loop, a curve, or some orientation other than a straight line so long as the resulting antenna has a low profile. The antenna legs, being made of conductive material, can take on a variety of construction techniques to address cost, mounting techniques, and desired signal pattern. In addition, in an alternate embodiment, the protective covering is not included and the antenna legs are directly mounted to a mounting surface with only the external coating serving as both a protectant and an adhesive. Also optionally, the protective covering and the external coating may be integral with each other, or they may comprise the same item or material, such as for example a plastic or rubber having adhesive qualities. As an

additional option, the protective covering and/or the external coating may be made of a material that partially or entirely degrades or disintegrates, thus leaving only one of the two materials to protect the antenna.

[0037] The preferred embodiment described above is illustrated in FIG. 1. Referring to FIG. 1, a dipole antenna includes conductive elements **1** and **2** that serve as the antenna legs. Preferably, the conductive elements **1** and **2** are flexible to allow the elements to be positioned in various locations. The conductive elements **1** and **2** are made of a conductive material such as copper wire, copper tape, or any other conductive material that may be molded or flattened and has a low profile.

[0038] An antenna cable **5** is attached to the antenna legs, preferably at or near the gap that separates the legs. The cable preferably includes at least two conductors so that one conductor can be attached to the antenna leg that serves as ground and the other conductor can be attached to the antenna leg that is designated as positive. As FIG. 1 illustrates, the cable may be positioned to extend from the legs in a direction that is perpendicular to the legs. Alternately, as illustrated in FIG. 2, the cable may run alongside the legs, or the cable may extend from the legs in any other direction.

[0039] Returning to FIG. 1, the elements are preferably encased in a flexible, non-conductive protective covering **3**. As noted above, the protective covering may be made of rubber, plastic, or any other non-conductive material. Although FIG 1 illustrates an embodiment where the elements are completely encased within the protective covering, optionally the protective covering may cover only a portion of the elements, such as the top of the elements.

[0040] Optionally and preferably, the conductive elements and/or the protective covering may be further encased in or covered by an external coating **4**. This external coating may be included with the antenna, or it may be added when the antenna is installed in its final service location. In a preferred embodiment, the external coating **4** is comprised of an epoxy, or of rubber or plastic with an adhesive, that serves to fixedly attach the antenna to a mounting surface. As illustrated in FIG. 2, the external coating **4** is preferably applied to all or part of the antenna wire **5** that is located above the mounting surface.

[0041] FIG. 3 provides a side view of the preferred embodiment of FIG.1 and illustrates that the conductive elements **1** and **2** are covered by the protective covering **3**, which is in turn covered by the external coating **4**. In an alternate embodiment, protective covering **3** is not included and the antenna legs are directly mounted to a mounting surface with only the external coating **4** serving as both a protectant and an adhesive. Also optionally, protective covering **3** and external coating **4** are integral or the same item or material.

[0042] The final assembly consists of placing the antenna wire through a suitably sized hole in the mounting surface or running the wire alongside or nearby the antenna legs to a point where the antenna wire can be routed to its final connection to the transmitter and/or receiver. For example, the transmitter/receiver may be mounted inside of a manhole, and the antenna may be installed on the manhole cover, as shown in FIG. 4, or in a groove of the manhole cover, as shown in FIGs. 5 and 5A, by threading the wire through a hole in the manhole cover, attaching the wire to the antenna legs, preparing the antenna legs to adhere to a mounting surface such as by adding an adhesive, and placing the antenna legs on the manhole cover or within one or more grooves in the manhole cover so that the adhesive attaches the antenna legs to the mounting surface. The antenna wire is also attached to

the transmitter/receiver within the manhole. Preferably, a disconnect is included between the antenna and the transmitter/receiver to allow removal of the manhole cover without damaging the antenna, the wire, or the transmitter/receiver.

[0043] Optionally and alternatively, the antenna may be mounted on a surface other than the manhole surface, such as on a roadway, or even partially or completely embedded within and/or flush with the surface, as shown in FIG. 6, such as in concrete, asphalt, other pavement, or even a floor or wall that is subject to traffic or force. In such an embodiment, the wire may be run to the manhole cover to be passed through a hole, or it may enter the manhole through a hole in the manhole side or a location other than the cover as shown in FIG. 6. It may also be passed through other locations, such as storm sewer grates, tire or track grooves, irrigation system recesses, or other locations In such configurations, the wire may run along a surface, or it may be positioned within a groove, a trench, a conduit, or another enclosed or partially enclosed location. FIG. 3 illustrates an example of an antenna that is capable of such a configuration.

[0044] In a particularly preferred embodiment, the antenna of the present invention is a dipole antenna in which the elongated conductive elements are positioned within a groove of the mounting surface in a substantially straight line, the connecting cable is inserted through a hole in the surface and extends to a cavity beneath the surface, and the antenna sealed into the surface with an epoxy specially formulated to adhere strongly and permanently to the surface, as is well known in the art. FIGs. 5, 5A, and 6 illustrate various aspects of this embodiment. FIG 5. a manhole cover **7** with the antenna mounted in a groove in the surface of the manhole cover that is continuos with a hole through the manhole cover. Coaxial cable **5** is shown extending through the hole to the cavity beneath the manhole cover. FIG. 5A illustrates detail of this embodiment wherein it is shown that

elongated elements **1** and **2** (which extend above and below the plane of the drawing) are wrapped in protective covering **3** and embedded within external coating **4**. While this illustration shows the antenna with its protective and external coatings having a low profile above the surface of the manhole cover, it should be understood that those elements may be just as well installed perfectly flush with the upper surface of the manhole cover. FIG. 6 shows the antenna of the present invention mounted in a traffic surface wherein the elongated elements (not shown) are positioned in a groove of the surface and a hole has been drilled into the surface through which antenna cable **5** has been passed.

[0045] As an additional option, the wire may be passed through an existing hole in the manhole or manhole cover, or a hole may be drilled for insertion of the wire. In such a configuration, the hole, after the wire is passed through it, is preferably filled with an epoxy and/or a sealant.

[0046] The construction of the antenna as a dipole provides two "legs," or antenna elements, having substantially equal lengths and extending in opposite directions from a central point. Prior art dipole antennas generally must be mounted a distance, typically one-half-wavelength or more above the ground. This antenna, however, is specially tuned to optimize performance in a low profile configuration. Specifically, the leg lengths are specially tuned to compensate for the antenna's close proximity to other construction features. Preferably, in an embodiment of this invention where the frequency of the transmitter is consistent with that of a wireless telephone, the overall combined length of the legs is between about six-and-one-half and about seven-and-one-half inches. Surprisingly and advantageously, we have found that such a length yields satisfactory results when the antenna is on or flush with a surface. This also satisfies the antenna impedance requirements for the connected transmitter and/or receiver.

[0047] The low profile of the antenna allows unique mounting opportunities. When attached to a flat surface, it provides for a low profile above the flat surface, helping to make the antenna resistant to damage from objects moving across the surface. When mounted on a textured surface it may be oriented to utilize any surface pattern which will allow the antenna to conform to surface recesses, thus making it low in height relative to the surface to which it is attached. Preferably, the height of the antenna is no greater than about one-quarter inch, although antennas having greater height may be used so long as the overall profile above ground is low or non-existent.

[0048] The low profile also allows for the use of an antenna assembly having more than one dipole element. In this optional configuration, each dipole element would be mounted side-by-side, substantially in parallel with a space between each dipole element. The dipole elements are each comprised of two "legs" but may be of different lengths, widths, and/or thicknesses to provide multiple transmission and/or reception frequencies. For example, a configuration may include a dipole element used for transmission on one frequency and a second dipole element used for reception on another frequency. Preferably, the multiple dipole elements are encased within a common protective covering and/or external coating. Also preferably, the external appearance of such a configuration is not substantially different from the appearance of an embodiment using only a single dipole.

[0049] This antenna offers particularly low cost of construction and allows varied installation techniques which can be tailored to the surface conditions presented at time of installation. The antenna design is also such that, when installed in locations such as manhole covers, the antenna is nearly invisible to the pedestrian, thus making it less susceptible to vandalism. Penetration requirements when mounted directly on the manhole are minimal compared to mechanically attached antennas.

[0050] The low profile of the present inventive antenna thus reduces or eliminates the susceptibility for damage of the antenna resulting from roadway traffic. For example, the present inventive antenna is non susceptible to damage from snow plows, street sweepers, and other such equipment that abrade the road surface. This invention also minimizes or eliminates any alteration of the manhole cover or other mounting surface itself for the purpose of installation. For example, many manhole covers are provided with grooves and/or small holes or other recesses, which this invention can use for mounting of the antenna. Prior art in this area requires substantial alteration of the manhole cover to allow mounting of the antenna. Where manhole covers are solid in construction, this invention requires only a small hole or slot to allow the antenna wire to pass from below the manhole cover to above the manhole cover. Prior art antennas of this nature require large holes to serve to secure the antenna to the manhole cover mechanically using a device that passes through the manhole cover.

[0051] Further, the low profile of the present inventive antenna reduces or eliminates the susceptibility for injury to pedestrians coming into contact with the antenna. The low profile makes it very unlikely that a pedestrian would trip over or catch his or her foot or clothing on the antenna. Thus, the present invention is useful for applications requiring the placement of an antenna in high foot-traffic areas, such as sidewalks, floors, decking, hallways and stairways.

[0052] Another improvement offered by this invention is the ease of installation. Through the use of fast curing adhesives or encapsulate materials, the antenna can be placed on the manhole or adjacent roadway and secured within a short period of time with minimal skill or tools required to complete the process. Optionally and preferably, no bolting or welding is required. This design produces an antenna that is relatively inexpensive when

compared to conventional antenna designs that rely more fully on mechanical mounting means and mechanical structure to make the antenna durable to roadway conditions.

[0053] This invention also permits mounting of the antenna on a manhole cover, or directly on or in the roadway with minimal excavation, to route the antenna wire or achieve a suitable cavity into which the antenna is secured using suitable adhesives or filler materials. Because the antenna is not totally rigid prior to installation, it offers flexibility during the installation process, even when installation conditions are less than ideal.

[0054] An alternative installation method involves placing the same style antenna element that is used on the manhole lid installation, into a permanently mounted position that is buried just below the surface of typical roadway surface materials. These materials can include but are not limited to concrete, brick, and asphalt. A narrow slot is cut into the material to allow placement of the antenna element just below the top surface of the material. Additionally, a hole is drilled to connect the slot with a nearby open area to provide a passage way for the antenna coaxial cable and associated connector. The drilled hole typically leads to the area where the connected radio equipment and instruments will be located. The antenna elements are then made waterproof by filling the slot with a specialized epoxy that is designed especially for sealing the type of material that the antenna is being embedded into.

[0055] The antenna offers several opportunities for delivery of data signals to or from the transmitter and/or receiver to which it is connected. For example, the antenna may be connected to a flow meter located within a sewer network, and the antenna could electrically transmit the data collected by the flow meter to a receiver such as a central data collection point, a mobile receiver such as a receiver mounted in a vehicle, or even a hand-held receiver.

[0056] The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, all of which may fall within the scope of the invention.